# SST Activity @ CNR

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GHRSST
GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE

ISMAR

# European Copernicus Programme& CNR

Marine Monitoring

GHRSST
GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE

Copernicus
Europe's eyes on Earth

**SATELLITES**

(S1, S3, Jason-3, S6, S2)

**IN SITU**

**SERVICES**

- MARINE — SST
- ATMOSPHERE
- LAND
- SECURITY
- EMERGENCY
- CLIMATE — SST

CNR-ISMAR has a leading role on Copericus Marine and Climate Services
CNR-ISMAR contribute to the space and in situ components: data and products requirements , product validation and design of the next generation of satellite missions and in situ infrastructures

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# CNR in CMEMS SST

## CNR involvement within the Copernicus Marine Environment Monitoring Service (CMEMS) elements

Copernicus Marine Service

### Monitoring and Forecasting Centres

### Thematic Assembly Centres

### Dissemination Unit

**CNR Coordinates**

**CNR Contributes**

# CNR Activity focus on SST

## CNR and SST products within the Copernicus Marine Environment Monitoring Service (CMEMS)

### Monitoring and Forecasting Centres

### Thematic Assembly Centres

### Dissemination Unit

**Producers of core SST products**

**Users of SST data**

**SST dissemination**

# CMEMS SST-TAC: CNR Products

## CNR SST Products within CMEMS

| Product reference | Title |
|---|---|
| SST_BS_SST_L3S_NRT_OBSERVATIONS_010_013 | Black Sea - High Resolution and Ultra High Resolution L3S Sea Surface Temperature |
| SST_BS_SST_L4_NRT_OBSERVATIONS_010_006 | Black Sea High Resolution and Ultra High Resolution Sea Surface Temperature Analysis |
| SST_BS_SST_L4_REP_OBSERVATIONS_010_022 | Black Sea - High Resolution L4 Sea Surface Temperature Reprocessed |
| SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012 | Mediterranean Sea - High Resolution and Ultra High Resolution L3S Sea Surface Temperature |
| SST_MED_SST_L4_NRT_OBSERVATIONS_010_004 | Mediterranean Sea High Resolution and Ultra High Resolution Sea Surface Temperature Analysis |
| SST_MED_SST_L4_REP_OBSERVATIONS_010_021 | Mediterranean Sea - High Resolution L4 Sea Surface Temperature Reprocessed |

NRT: products within few hours, NRT replaced by consolidated (DT) product after few days
REP: consistent re-processed time series

L3S: daily (merged-multisensor) products; L4 analysis (no data gaps)

L3S and L4 includes two datasets:

- High Resolution (HR): 1/16° (0.0625°) spatial resolution ;
- Ultra High Resolution (UHR): 0.01° spatial resolution

# CMEMS SST-TAC: CNR Products

## Main evolutions of CNR SST Products within CMEMS

- NRT products → ingestion of SLSTR data from Sentinel 3A/3B
  *S3A operational*
  *S3B under testing*

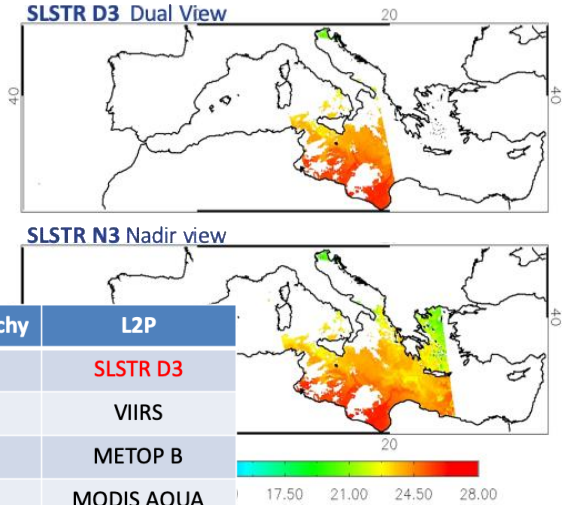
- REP products → move to ESA-CCI/C3S upstream data
  *planned for end of 2019*

# Use and impact of SLSTR3A on Mediterranean and Black Sea products

**Product ID: SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012,SST_MED_L4_NRT_OBSERVATIONS_010_004, SST_BS_SST_L3S_NRT_OBSERVATIONS_010_013, SST_BS_SST_L4_NRT_OBSERVATIONS_010_006**

- SLSTR3A data are downloaded via CODA (Copernicus Online Data Access)
- **Both Single and Dual view**, L2, **quality level 5** data are used
- **Dual** and **Nadir View** data are **treated separately**
- Conversion from skin SST to depth SST
- **Dual View** is used as the **reference for bias adjustment** of other sensors
- Single View is given a low rank in the sensor hierarchy

Sentinel 3A SLSTR data are used operationally since 23 March 2018




| Hierarchy | L2P |
|---|---|
| 1 | SLSTR D3 |
| 2 | VIIRS |
| 3 | METOP B |
| 4 | MODIS AQUA |
| 5 | MODIS TERRA |
| 6 | SLSTR N3 |
| 7 | SEVIRI |

**Impact of SLSTR3A:**

Assessments based on comparison with fully independent in situ SST data
- Validation period: July 2017 – March 2018
- Matchup Dataset: co-located (in space and time) satellite - drifter obs.

Validation showed a minor (though statistically significant) improvement

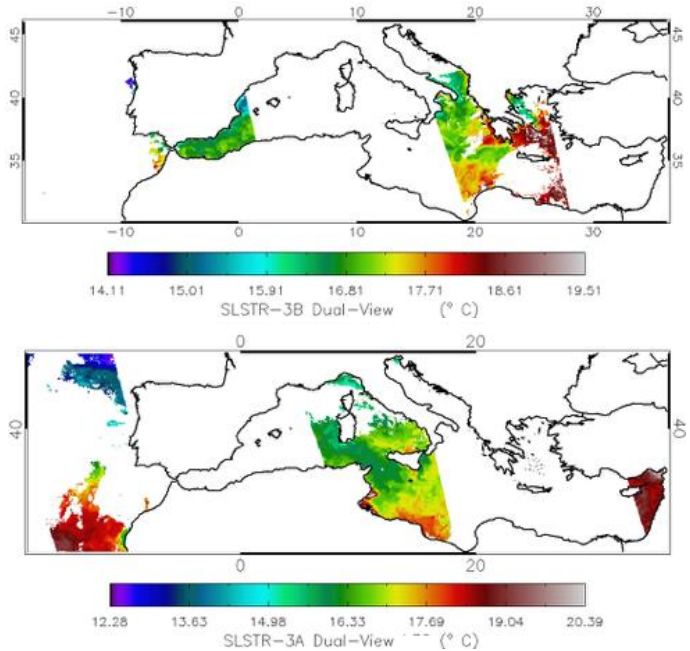
| MED L3S | MBE (°C) | STDDEV (°C) | RMSE (°C) | N_MUP |
|---|---|---|---|---|
| Upgrade to SLSTR | -0.15 ± 0.01 | 0.43 ± 0.01 | 0.46 ± 0.01 | 7694 |
| Ref. L3S | -0.24 ± 0.01 | 0.43 ± 0.01 | 0.49 ± 0.01 | 7579 |

| MED L4 | MBE (°C) | STDDEV (°C) | RMSE (°C) | N_MUP |
|---|---|---|---|---|
| Upgrade to SLSTR | -0.09 ± 0.01 | 0.41 ± 0.01 | 0.42 ± 0.01 | 10617 |
| Ref. L4 | -0.18 ± 0.01 | 0.41 ± 0.01 | 0.45 ± 0.01 | 10613 |

CMEMS SEA SURFACE TEMPERATURE TAC
MARINE ENVIRONMENT MONITORING SERVICE
Contract 78-CMEMS TAC SST Until 31 March 2021

# CMEMS SST-TAC: CNR Products

## Preliminary assessment of SLSTR3B on Mediterranean and Black Sea products




- Testing is underway for Sentinel 3B SLSTR
  - Expect to introduce this operationally in November
- Very preliminary comparison between L3C built using only SLSTR-3B/-3A Dual-View (March-April) shows slightly worse RMSD
- Coverage is clearly doubled compared to only Sentinel 3A SLSTR

| MED L3C | MBE (°C) | STDDEV (°C) | RMSE (°C) | N_MUP |
|---|---|---|---|---|
| SLSTR-3A | 0.09 ± 0.02 | 0.29 ± 0.02 | 0.30 ± 0.02 | 892 |
| SLSTR-3B | 0.07 ± 0.03 | 0.34 ± 0.03 | 0.35 ± 0.03 | 630 |

# CMEMS SST-TAC: CNR Products

## CNR REP SST products developments already carried out in 2019

Extension of MED/BS (P3, P6) time series with interim REP data for 2018. Since the CCI data were not yet available at this stage, the products will be extended to 2018 by including bias adjusted UHR NRT L3S data as input.

## CNR REP SST products developments planned before the end of 2019

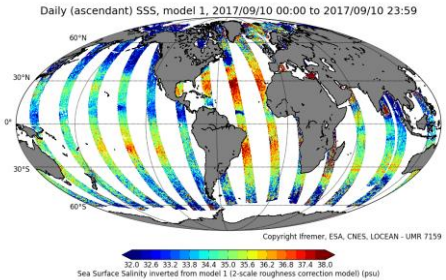
| Product reference | Update Title | PU |
|---|---|---|
| SST_BS_SST_L4_REP_OBSERVATIONS_010_022 | Reprocessing with ESA-CCI | CNR |
| SST_MED_SST_L4_REP_OBSERVATIONS_010_021 | Reprocessing with ESA-CCI | CNR |

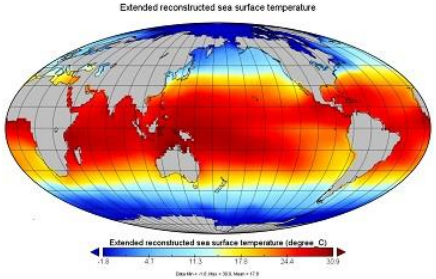
Mediterranean/Black Sea (P3/P6) reprocessing with ESA-CCI and regular updates with C3S data. A new reprocessing will be completed, producing daily fields from 1982 to present. The reprocessing will use the SST CCI satellite products for the first part of the record and SST products from C3S for the yearly updates.

# CMEMS MULTI-OBS: CNR Products

## Usage of SST L4 data within multivariate SSS processing chain

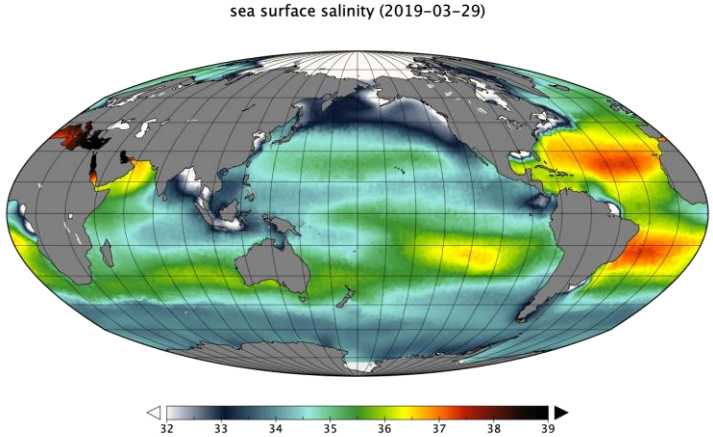
MULTIOBS_GLO_PHY_NRT_015_001/ MULTIOBS_GLO_PHY_REP_015_002 :
Global Multi-Year and Near-Real-Time Sea Surface Salinity and Density L4 dataset



Multivariate Optimal Interpolation algorithm

The SSS-SSD optimal interpolation is based on a multidimensional (space/time/thermal) covariance model, using Reynolds L4 in input
Plan to move to OSTIA REP L4 based on ESA-CCI/C3S in future updates




**Input data stream**:
Quality controlled in situ SSS/SST used in **ARMOR3D**
SMOS – L2Q daily from **CATDS**

**Background**:
output of first round of OI starting from in situ input data
and monthly climatology built from sss-ssd-rep (previous version)

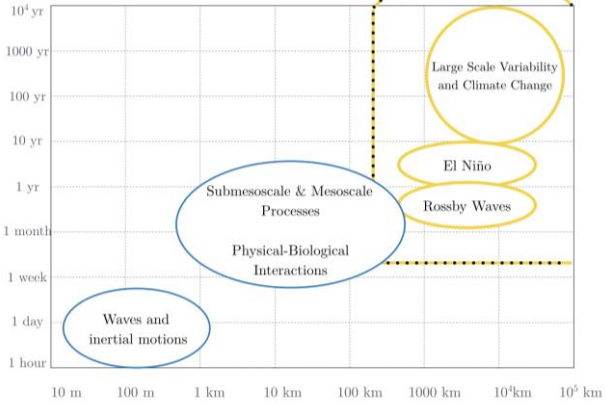
Consistent NRT/REP data online since April 2019

# Applications of SST:
# Space-based sea surface currents retrieval

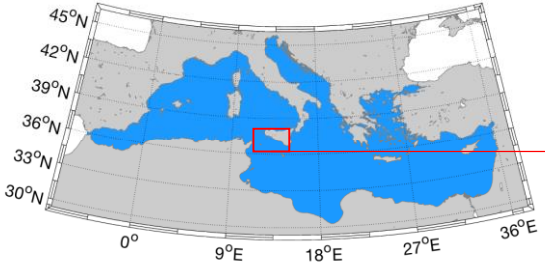
## Optimization of the altimeter-derived currents: regional application, MED SEA - context

$$(u_g, v_g) = \frac{g}{f}\left(-\frac{\partial h}{\partial y}, \frac{\partial h}{\partial x}\right)$$

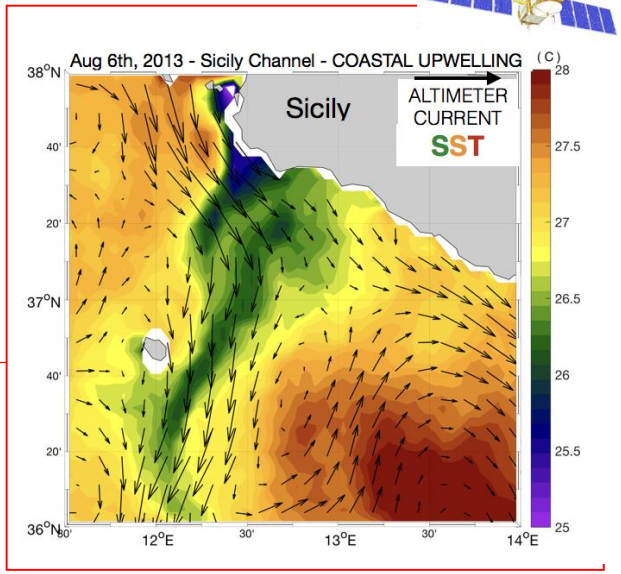
$h$=sea level




The altimeter system allows to monitor the large-scale geostrophic component of the sea-surface currents:
Incomplete description of the Mediterranean Sea surface circulation
Rossby deformation radius ~10-20 km




Example of the Altimeter system in non-geostrophic circulation




**New methodologies have to be explored** to go beyond the altimeter system limitations
**We rely on** the patterns of a high-resolution surface tracer: **Sea-Surface Temperature**

Poster 11
Group E
Thursday

Ciani et al. Remote Sensing 2019; Rio and Santoleri Rem. Sens of the Env. 2018

# Optimization of the altimeter-derived currents: regional application, MED SEA – methods and results

**CMEMS Altimeter Currents**
dt = 1 day
dx = 1/8°

**CMEMS SST**
dt = 1 day
dx = 1/24°

**OPTIMAL RECONSTRUCTION**
Rio and Santoleri 2018
Piterbarg 2009

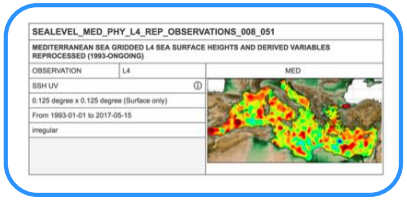
↓

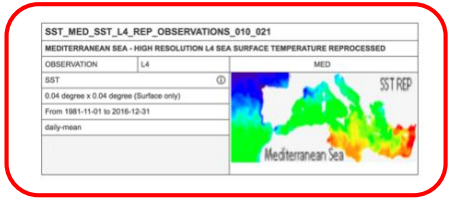
**OPTIMAL CURRENTS**
dt=1 day
dx=1/24°

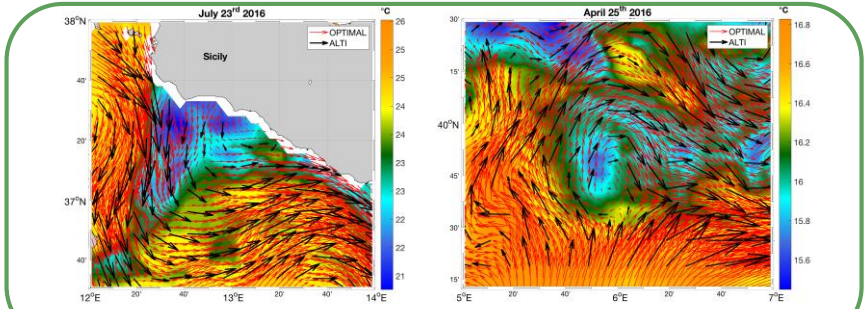
↓

**VALIDATION using**
**OGS-NODC**
**Drifting buoys**

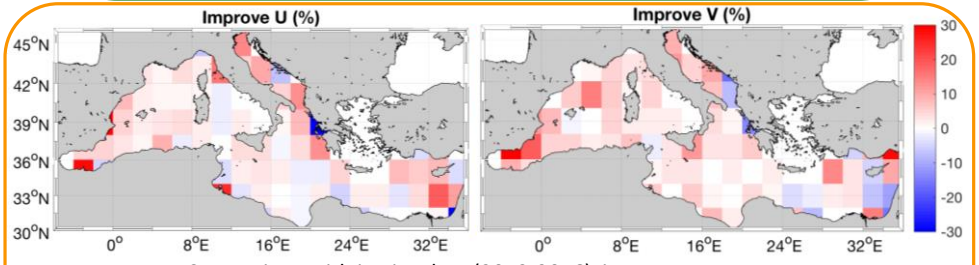
**Comparison of Altimeter and Optimal Currents**




Improved description of small-scale, non geostrophic features due to SST

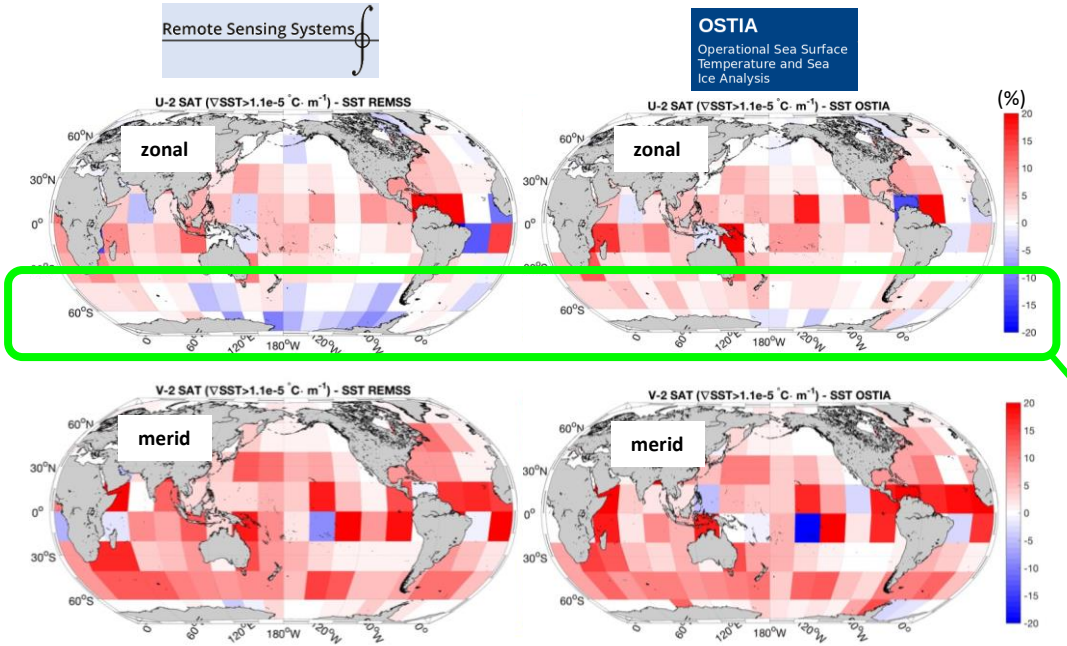



Comparison with in-situ data (2012-2016), improvements up to 30% locally with respect to the altimeter estimates

Ciani et al. 2019, Rio and Santoleri 2018

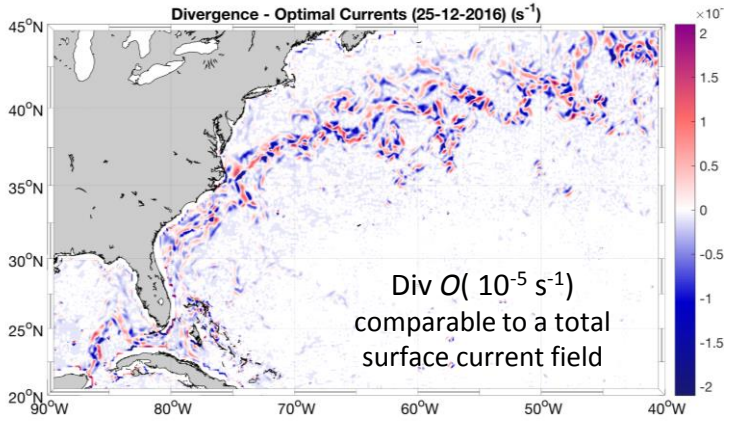
# Optimization of the altimeter-derived currents: global scale study

**Support during final phase of Globcurrent** Project : Improved global currents based on **DUACS 18** Geostrophic Currents and **REMSS/OSTIA SST (2014-2016)**




**Percentage of improvement with respect to DUACS18, based on comparisons with the GDP buoys measurements**

REMSS (MWIR) SST: overall better performances at global scale.
OSTIA SST: issue on the zonal degradation at high-latitudes is solved




OSTIA: zonal degradation in the southern ocean disappears

The quality of the SST data is crucial!
**Benefits** from the potential **CIMR** observations
sub-daily full coverage at high latitudes and daily global high-resolution SST

Ciani et al. 2019, in prep.

# CNR & Copernicus Climate Service

## CNR Coordinates the C3S_511 Service on the Scientific Quality Assessment and Report for ECVs

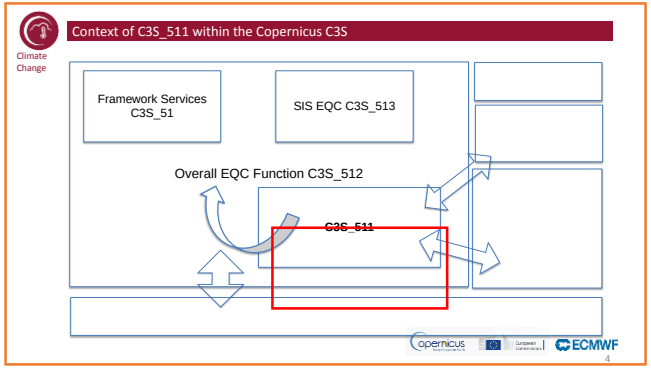
In partnership with:
DLR ETHZ LMU UCL UVB CLU-SRL CSIC IOP-PAN ENEA

**OBJECTIVE: Address the quality assessment of observed ECV products in Climate Data Records for C3S and compare with existing independent CDRs.**

→ CDS dataset are singularly assessed by providers with different approaches, methods.
→ Datasets have a different degree of maturity

**C3S_511 reviews independently and provides a uniform assessment of all ECVs (Atmosphere – Ocean – Land)**
What they can be used for …
Which climate applications may benefit of such data

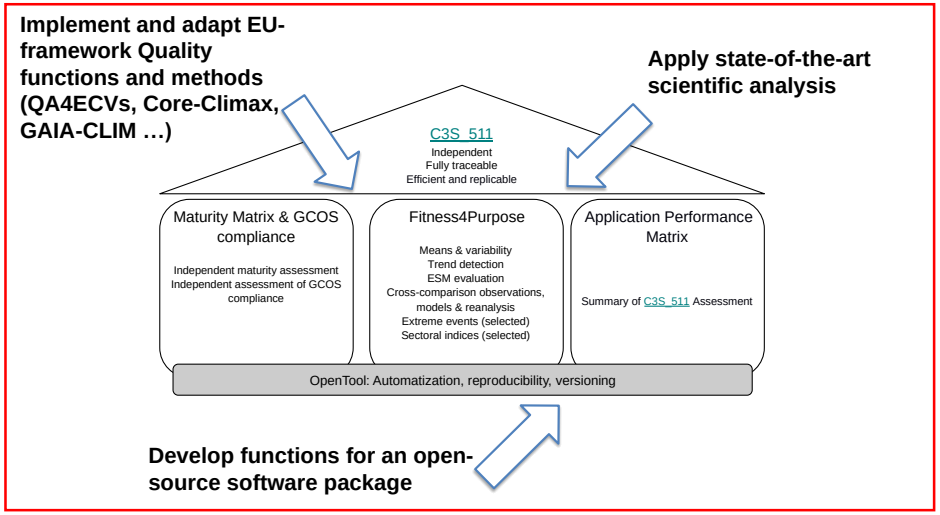
Under the form of synthetic and appealing reports on quality and applicability

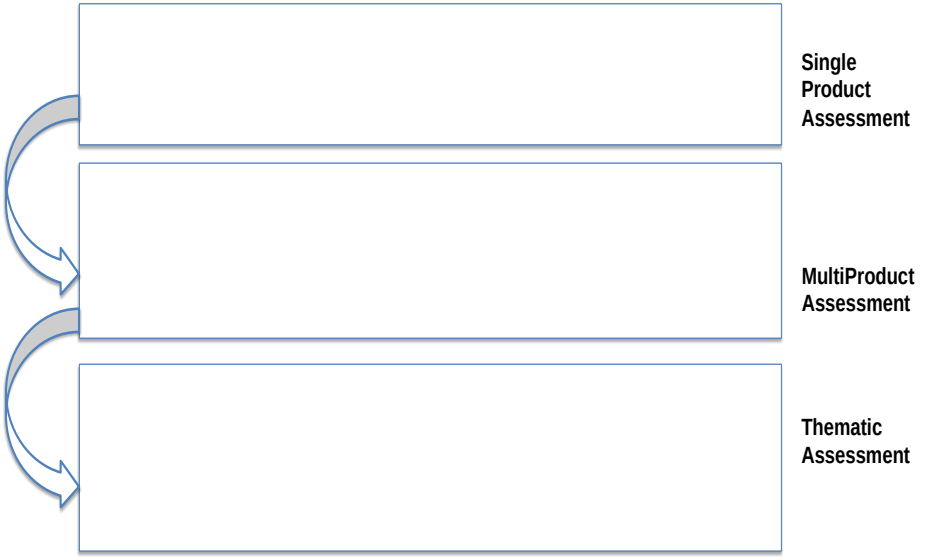



SST evalution is part of the game
C3S_511 evaluates all the SST dataset available on the CDS (SST-CCI, C3S, ERA5, ORA5,..)

# C3S_511 QA framework: How we build the EQC functions

*Bringing Climate Science to Users*




First step focus on:

- Definition of the framework
- single product assessment (V1) for selected variables and datasets

# C3S_511 Single Product Quality Brief: SST



Title

- Product type
  - Satellite observations (5)
- Variable domain
  - Atmosphere (composition) (3)
  - Atmosphere (surface) (4)
  - Atmosphere (upper air) (4)
  - Land (biosphere) (1)
  - Land (cryosphere) (2)
  - Land (hydrology) (3)
  - Ocean (physics) (5)
- Spatial coverage
  - Global (2)
- Temporal coverage
  - Past (5)

## Sea level daily gridded data for the Black Sea from 1993 to present

Sea level anomaly is the height of water over the mean sea surface in a given time and region. Up-to-date altimeter standards are used to estimate the sea level anomalies with a mapping algorithm dedi...

## Sea level daily gridded data for the global ocean from 1993 to present

Sea level anomaly is the height of water over the mean sea surface in a given time and region. In this dataset sea level anomalies are computed with respect to a twenty-year mean reference period (199...

## Sea surface temperature daily gridded data from 1991 to 2010 produced by ESA-CCI

This dataset provides daily values for sea surface temperature and sea ice fraction over a regular grid with no missing values in space or in time. The initial satellite data from the Along Track Scan...

## Sea level daily gridded data for the Mediterranean Sea from 1993 to present

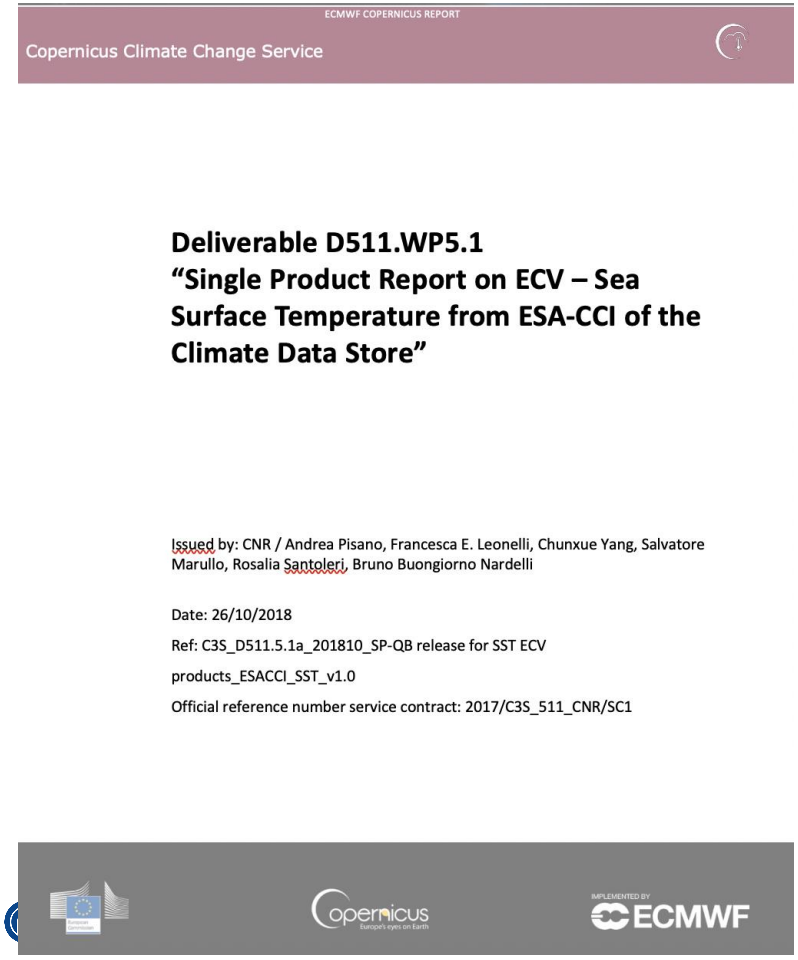
Sea level anomaly is the height of water over the mean sea surface in a given time and region. In this dataset sea level anomalies are computed with respect to a twenty-year mean reference period (199...

## Sea ice monthly and daily gridded data from 1978 to present

This dataset provides daily values for sea ice concentration, sea ice edge and sea ice type and monthly values for sea ice thickness. These four variables are important markers for climate change stud...

# The Filled SPQB for ESA-CCI SSTs



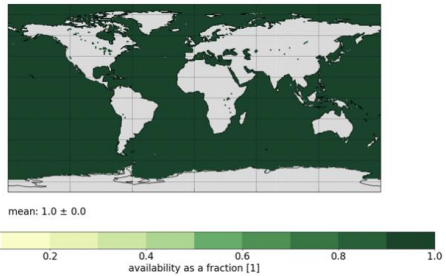



| | |
|---|---|
| General Description | The ESA-CCI Sea Surface Temperature (SST) Level 4 (L4) product (version 1) provides daily global spatially complete SST fields at 0.05° spatial resolution, covering the period from 1st September 1991 to 31st December 2010. The ESA-CCI SST L4 product is built by interpolating reprocessed satellite data from (A)ATSR and AVHRR sensors with the OSTIA (Operational SST and Sea Ice Analysis) system [1] and are designed to represent the daily average SST at the nominal depth of 20 cm. The main characteristics of this product are its homogeneity and stability through the time series, its independence from in situ data and uncertainty estimates associated to each SST value, making this product suitable for climate applications [2, 7]. Detailed information on the ESA-CCI SST L4 product can be found in the algorithm theoretical basis document [3], product user guide and specification document [4, 5] and validation and climate assessment results [6, 7] as well as file format specification [8]. |
| Horizontal Resolution | 0.05 degrees |
| Temporal Resolution | Daily |
| Spatial Coverage | Global |
| Temporal Coverage | 09/1991-12/2010 |
| Variables | Sea Surface Temperature [K] |
| Format | NetCDF – CF Convention compliant |
| Comments | The evaluation of the ESA-CCI SST L4 product has been carried out using the ESMValTool (version 1) software, which first requires data to be in a CMOR (Climate Model Output Rewriter) format. Since the ESA-CCI SST L4 data in the CDS are not fully CMOR compliant, we had to carry out the cmorization of data using NCO and CDO operators. Then, since ESMValTool v.1 handles only a limited amount of memory volume, we had to downgrade the input CMOR data from 0.05° to 1° spatial resolution while maintaining the original daily temporal resolution. Finally, since ESMValTool handles only complete years, the year 1991 has been excluded from the evaluation. |

## 2. Executive summary

### 2.1 Basic evaluation

**Completeness and coverage**




The evaluation of the ESA-CCI SST L4 data availability shows that the product does not present gaps either in space or in time, in accordance with the spatially and temporally complete nature of the product. As such, it is potentially suitable for climatic applications at the global scale.

**System maturity matrix**

System Maturity Matrix

| Software Readiness | Metadata | User Documentation | Uncertainty Characterisation | Public access, feedback, and update | Usage |
|---|---|---|---|---|---|
| Coding Standards | Standards | Formal description of scientific methodology | Standards | Public Access/Archive | Research |
| Software Documentation | Collection level | Formal validation report | Validation | Version | Decision support system |
| Numerical Reproducibility and portability | File level | Formal product user guide | Uncertainty quantification | User feedback | |
| Security | | Formal description of operations concept | Automated quality monitoring | Updates to record | |
| 1 | 2 | 3 | 4 | 5 | 6 |

The System Maturity Matrix of the ESA-CCI SST L4 product has been filled based on the CORE-CLIMAX approach. The ESA-CCI SST L4 product fulfills the highest scores requirements. Some categories are left blank on purpose since not applicable at this stage.



### 2.2 Fitness for Purpose

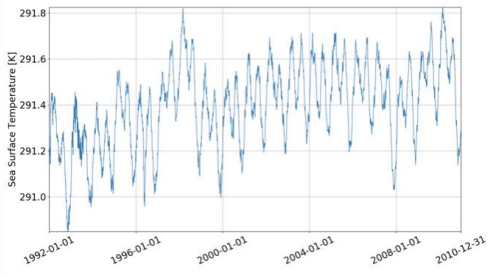
**GCOS Requirements**

GCOS requirements

| Frequency | Resolution | Accuracy | Stability |
|---|---|---|---|
| Hourly to monthly | 1-100 km | 0.1 K over 100 km scales | < 0.03 K over 100 km scales |
| 1.0 days | 0.05 degrees | 0.22/0.46 K | -1.8/22.1 mK/year |

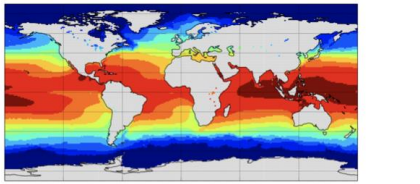
The ESA-CCI SST L4 data available from the CDS have a daily sampling frequency and a spatial resolution of 0.05° degrees, thus fulfilling the GCOS requirements in terms of frequency and resolution [9]. The stability and accuracy of the ESA-CCI SST L4 product have been assessed by the data producers [6, 7] and in Merchant et al., 2014 [2]. For the period 1991-1995, stability was found to range between -1.8 and 22.1mK/year (95% confidence level) while for the period 1995-2010 the range was 0.1 to 3.2mK/year (95% confidence level). Excluding the period prior to 1995, the stability of the ESA-CCI SST L4 product falls marginally outside the GCOS stability requirements, i.e. < 3mK/year. Validation statistics based on a comparison of co-located (in space and time) ESA-CCI SST L4 data and reference in situ measurements show that the accuracy of the ESA-CCI-SST L4 product ranges from 0.22K to 0.46K thus approaching the GCOS target accuracy.

**Use case 1: Means and variability**



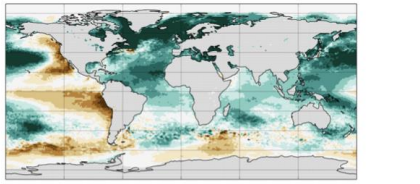
# C3S_511 Single Product Quality Brief: SST

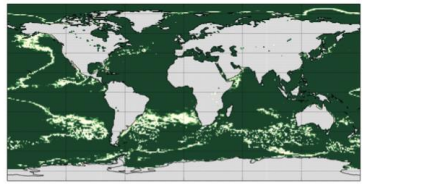





With its high spatial and temporal resolution, the ESA-CCI SST L4 product is able to resolve the main features of the global ocean circulation, such as ocean surface thermal fronts and currents systems (e.g., the Gulf Stream). The temporal span of the ESA-CCI SST L4 product is able to resolve inter-annual variability and to capture climatic modes characterized by comparable variability (temporal duration), such as El Nino-Southern Oscillation (ENSO) and the Indian Ocean and Tropical Atlantic Dipoles. However, a longer temporal span is needed to fully resolve multi-decadal variability, as e.g. the Pacific Decadal Oscillation (PDO) and the Atlantic Multi-decadal Oscillation (AMO). Since the analysis has been carried out on a 1° spatial resolution, some of the spatial features could be filtered out, which however are well reproduced in the original (full spatial resolution) ESA-CCI SST L4 product [2, 7].

Use case 2: Trends and their limits




The ESA-CCI SST L4 product is relatively short (19 years) and a linear trend can only provide a general picture of what has happened to the SST in this period. In particular, a consequence of having only 19 years of data is that the long-term warming trend during this period could be affected by inter-annual variability, which is dominated by the strong El Niño/La Niña events around 1997-2000 and from 2007-2010. Therefore, a longer time record is needed to better remove inter-annual and inter-decadal variability. The global average linear trend is estimated as 0.015K/year ± 0.029, which corresponds to an average total increase of 0.3°C over this 19-year period. This trend estimate is consistent with the literature [10].

Use case 3: Applicability for ESM validation

ESM Evaluation Table and Grading

| Mean Climatology | Trend | Variability |
|---|---|---|

The stability and accuracy of the ESA-CCI SST L4 product has been fully assessed by the data producers [2, 6, 7]. Results on both stability and accuracy assessment show that the ESA-CCI SST L4 product falls marginally outside the GCOS stability requirements. In addition, the independence of the ESA-CCI SST L4 product from in situ data and the availability of uncertainty estimates associated to each SST value makes this product suitable for ESM evaluation in terms of mean climatology, linear trend and variability analysis.

First Version of the SST report. New version next year

# C3S_511 Single Product Quality Brief

**SPQB already DELIVERED to ECMWF and will be available soon to the users:**

## Atmospheric ECVs

- **Temperature, dataset: ERA5**
- **Wind, dataset: ERA5**
- **Humidity, dataset: ERA5**
- **Ozone, dataset: ESA-CCI, 4 different products:**
  1. **GOME-type Total Ozone ECV– column**
  2. **OZONE LMZ-MERGED - profiles**
  3. **OMI-AURA Profiles**
  4. **IASI-B Tropospheric column**
- **Methane, dataset:**

## Oceanic ECVs

- **SST, datasets: ERA5 & ESA-CCI**
- **Sea level, dataset: C3S (altimeter), ORA5**
- **Surface current: ORA5**
- **Surface fluxes: ERA5**
- **surface salinity:ORA5**

## Land ECVs

- **SoilMoisture: ERA5**
- **albedo:**
- **Glaciers: Randolph Glacier Inventory, CGLS**

## Surface ECVs

- **Surface temperature: ERA5**
- **Wind: ERA5**

**Deliverable D511.5.1a**
**SP-QB release for SST ECV products**

"Single Product Report on ECV – Sea Surface Temperature from ESA-CCI of the Climate Data Store"

Issued by: CNR / Andrea Pisano, Francesca E. Leonelli, Chunxue Yang, Salvatore Marullo, Rosalia Santoleri, Bruno Buongiorno Nardelli

Date: 26/10/2018

Ref:C3S_D511.5.1a_201810_SPQB_release_for_SST_ECV_products_ESACCI_SST_v1.0

Official reference number service contract: 2017/C3S_511_CNR/SC1

# C3S_511 Application Perfomance Matrix: SST



| | |
|---|---|
| **Database name** | Sea Surface Tempeature |
| **Evaluated by** | CNR / Chunxue Yang & Federico Fierli |
| **Date** | 13/09/2018 |
| **Comments** | Dataset downsized with CDS-Toolbox |

| Climate applications | Extreme Events | Sectoral Information Systems |
|---|---|---|
| Means and variability 🙂 | Heat | Water management |
| Trends | | Agriculture and Forestry |
| Earth System Models applicability | | Insurance |
| GCOS ⚙ | | Energy |
| | | Infrastructure |
| | | Transport 🙂 |
| | | Health |
| | | Coastal Areas |
| **Comments** | **Comments** | **Comments** |

**Score**

- Not Fit
- Partly fit
- Fully Fit
- Assessment not already performed

Check comments and tables

**Completeness**

- 🙂 Assessment complete
- ⚙ Partly complete

**Find what can be done with this dataset Performance on the Applicability**

**Synthetic text with expert's indications specific for each product**

**Scores leading to guidance**

Climate Change Service

ENEA

# C3S_511 Application Perfomamce Matrix



**Application performance Matrix**

| Applicability to climate analysis | Use Cases | Applications |
|---|---|---|
| Length of the timeseries | Earth System Models applicability | Water management |
| Homogeneity of timeseries | GCOS requirements | Agriculture and Forestry |
| Temporal resolution | Extreme Events: Heat | Insurance |
| Spatial coverage | Extreme Events: Drought | Energy |
| Spatial resolution | Extreme Events: Cold | Infrastructure |
| Amount and distribution of data gaps | Extreme Events: Precipitation | Transport |
| Uncertainty information | | Health |
| Trend detection | | Coastal Areas |
| Comments - Synthesis (20 lines) with key references and salient points from the main report | | |

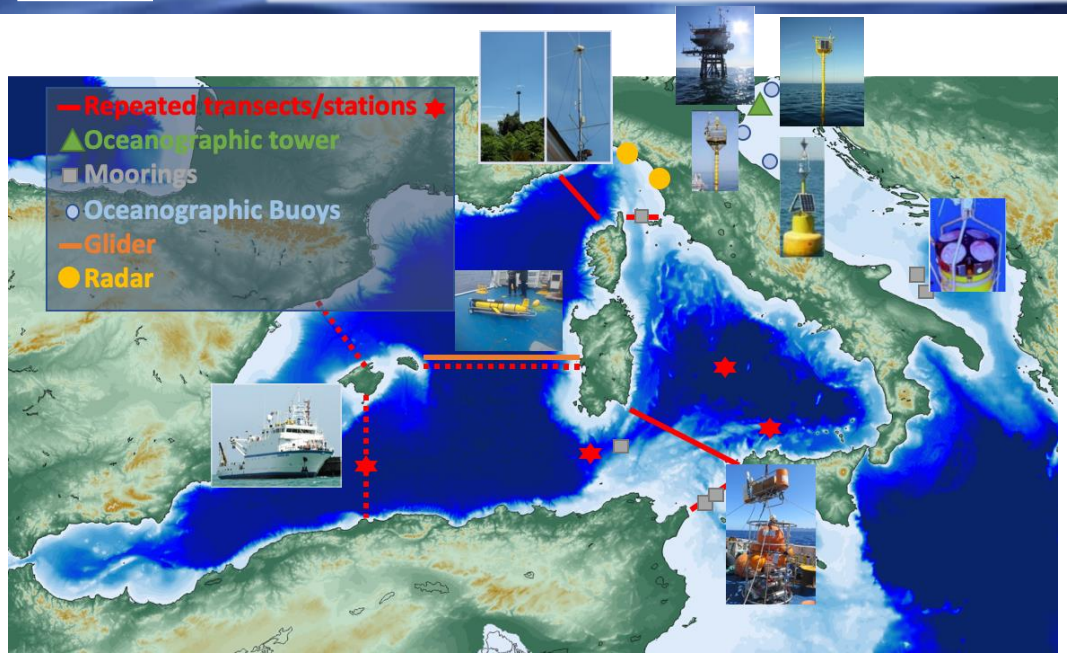
| Score | | Completeness |
|---|---|---|
| Not Fit | | Assessment complete |
| Partly fit | Check comments and tables | Partly complete |
| Fully Fit | | |
| Assessment not already performed | | |

For each Application an APX will be produced for each ECV/datasets (SST)

APX evalution based on user requirements

APX in under defintion

# Istituto di Scienze Marine




*Piattaforma-acqua-alta*

**Almost 50 years of observational activity and national and international cooperations.**

THANK FOR YOUR ATTENTION